

AD-A057238

LEP-L

USADACS Technical Library



5 0712 01014212 2

TECHNICAL  
LIBRARY

AD

AD-E400 152

TECHNICAL REPORT ARLCD-TR-77054

THE EFFECTS OF CHANGES IN FLARE INTENSITY  
ON THE RECOGNITION PROBABILITY OF  
VEHICULAR SIZE TARGETS

ROBERT B. DAVIS  
JESSE F. TYROLER

APRIL 1978



US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND  
LARGE CALIBER  
WEAPON SYSTEMS LABORATORY  
DOVER, NEW JERSEY

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

The findings in this report are not to be construed as an official Department of the Army position.

#### DISPOSITION

Destroy this report when no longer needed. Do not return to the originator.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCD-TR-77054	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE EFFECTS OF CHANGES IN FLARE INTENSITY ON THE RECOGNITION PROBABILITY OF VEHICULAR SIZE TARGETS		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Robert B. Davis Jesse F. Tyroler		8. CONTRACT OR GRANT NUMBER(s) AMCMS Code 5396.0M.6350.1.04
9. PERFORMING ORGANIZATION NAME AND ADDRESS Explosive Division Feltman Research Laboratory Picatinny Arsenal, Dover, NJ 07801		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARRADCOM ATTN: DRDAR-TSS Dover, NJ 07801		12. REPORT DATE APRIL 1978
		13. NUMBER OF PAGES 28
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) US Army ARRADCOM, LCWSL Energetics Materials Division Dover, NJ 07801		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES This information was prepared at the request of the Army Materials and Mechanics Research Center, Watertown, MA.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Flare illumination                      Terrain model Recognition probability              Critical illumination level Target recognition Search		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The present specifications on minimum acceptable flare intensity are made without any quantitative information on how reductions in intensity influence an observer's ability to recognize targets. A study was conducted, using the Pyrotechnic Terrain Model, to examine the relationship between changes in the intensity of flares and tar- get recognition. Four separate cases were examined having different illumination re- quirements for recognition. Using these data, three types of illumination flares at		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

~~UNCLASSIFIED~~

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20. (Cont'd)

three ranges were evaluated to show the decrease in recognition and recognition areas with decreasing intensities.

~~UNCLASSIFIED~~

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

### ACKNOWLEDGMENT

The assistance of Mr. Gene D. Venable and Mr. Henry Widmann in the collection of data and preparation of this report is sincerely appreciated by the authors.

## TABLE OF CONTENTS

	Page No.
Introduction	1
Tests	2
Procedures	2
Discussion of Results	3
Flare Applications	4
Fixed Position	4
Specific Areas	4
Search	4
Figures of Merit	4
Fixed Position	5
Specific Area	5
Search	6
Approximate Effects	6
Fixed Position	6
Specific Area	6
Search	8
Conclusions	8
Distribution List	17
Tables	
1 Effect of flare intensity on area illuminated	9
2 Effect of flare intensity on target recognition	10

## Figures

- 1 Recognition response to vehicular size targets  
against a medium green background at a simulated  
range of 490 m (1500 ft) and a target illumination  
angle of  $124^{\circ}$  11
- 2 Recognition response to vehicular size targets  
against a dark green background at a simulated  
range of 654 m (2000 ft) and a target illumination  
angle of  $90^{\circ}$  12
- 3 Recognition response to vehicular size targets  
against a medium green background at a simulated  
range of 980 m (3000 ft) and a target illumination  
angle of  $110^{\circ}$  13
- 4 Recognition response to vehicular size targets  
against a dark green background at a simulated  
range of 1150 m (3500 ft) and a target illumination  
angle of  $70^{\circ}$  14
- 5 Portions of the response curve normalized at  
the critical illumination level 15
- 6 Average curve of the four normalized  
response curves 16

## INTRODUCTION

Few successful field tests have been conducted in the past to determine the level and duration of illumination required from flares for the detection, recognition, and identification of standard military targets. Tests utilizing flares suspended by parachutes as a source of illumination had many serious disadvantages such as flicker, nonreproducibility of light levels, movement of the flare during burning, smoke, and unpredictable flight paths caused by wind changes. As a result it is virtually impossible to reproduce any set of conditions in order to examine the effect on performance of a change in one parameter, and the data gained from such tests provide little quantified information and are consequently of little value. Furthermore, since the actual flares used are generally of a multimillion-candlepower type, electrical sources which can be utilized to simulate the characteristics of a flare are completely impractical.

To overcome these problems, to provide valid statistical data for use in the field, and to eliminate expensive field tests, a model terrain program was initiated. The model terrain presently being utilized is a Southeast Asian type scaled at 160:1. The system can simulate exactly all the known parameters in a flare including flicker, spectral distribution, wind drift, oscillations, etc. As a result, it is possible for the first time to investigate the effect of each parameter of flare illumination in an area of interest with a quantitative and statistically sound procedure.

The pyrotechnic illumination model, the basic vehicle which is used in this program, has been used successfully in programs determining the illumination levels required for recognizing a variety of military targets under various conditions. The following reports on these studies have been published:

Picatinny Arsenal Technical Report (PATR) 4075, "Pyrotechnic Terrain Model, A New Dimension in Pyrotechnic Evaluation, Description and Initial Results," December 1970, by Jesse F. Tyroler.

PATR 4184, "Results of an Illumination Requirement Study Using a Pyrotechnic Terrain Model," November 1971, by Robert B. Davis.

## TESTS

### Procedures

The observers used for these tests were U.S. Army personnel having normal vision, either natural or corrected. They were given an orientation on the terrain model, the targets to be recognized, the method of target presentation, and the type of responses desired such as, "Large truck, side", or "Jeep, front". Subsequently they were "dark-adapted" for at least 30 minutes and positioned at the proper distance. The simulated flare was positioned in the desired orientation with respect to the observer and targets. The level of illumination was fixed, and the observer responded to the vehicular-size targets presented. After completing a series of observations, the illumination level was lowered approximately 20% and the same procedure followed until the illumination level was insufficient and recognition was no longer possible.

The illumination was measured with a Weston Model 1979 Illumination Meter which was modified for greater sensitivity. The illumination levels reported are given in terms of the footcandles on a surface at the target perpendicular to the source.

Four tests were conducted to determine the probability of recognition of military, vehicular-size targets. The specific conditions of these tests were:

1. Target illumination angle, 90°; simulated range, 660 m (2000 ft); background, dark-green, grassy area; observations from ground level.
2. Target illumination angle, 124°; simulated range, 490 m (1500 ft); background, medium-green, grassy area; observations from ground level.
3. Target illumination angle, 70°; simulated range, 1150 m (3500 ft); background, dark-green, grassy area; observations from ground level.
4. Target illumination angle, 110°; simulated range, 980 m (3000 ft); background, medium-green, grassy area; observations from ground level.

These four conditions were selected to ensure a distinctly different illumination-level requirement in all cases and also because they were easily accessible positions on the terrain model. A total of 14 observers were used for these tests. They performed more than 16,500 separate observations in compiling the data. The resulting curves of Percent Recognition versus Illumination Level are shown in Figures 1, 2, 3, and 4.

### Discussion of Results

It can be seen that in these four distinctly different cases all the curves exhibit a characteristic behavior, i.e., as the illumination level is increased, recognition increases rapidly until a plateau is finally reached at approximately the 90-95% recognition level where further increases in illumination have little or no effect on increasing recognition. This point on the recognition vs illumination level curve in this report will be referred to as the "critical illumination level" and, of course, is a different illumination level for each case.

If these four curves are normalized and plotted with Percent Recognition as the ordinate and Fraction of Critical Illumination as the abscissa, Figure 5 is obtained. It can be seen that all four normalized curves are very similar. The average of these four curves is plotted in Figure 6 and can be represented by the function

$$P = 1.25e^{-\frac{0.42}{F}} + 0.031$$

where P is the probability of recognition and F is the fraction of critical illumination at the target. This average curve is very significant and can be very useful for estimating some effects of variation in flare intensity on actual performance. For example, assume that Figure 6 approximates the percent recognition as a function of the fraction of critical illumination independent of the critical illumination level and the relative positions of target, observer, and flare (a reasonable assumption since it was true in the four distinctly different cases described). It can be concluded that if a target is illuminated by a flare from a fixed position relative to an observer and if the illumination level is above the critical illumination level, then changes in intensity in the flare (the illumination on the target being proportional to the intensity of the flare) will have little effect on the observer's ability to recognize the target. If the illumination is below the critical illumination level, changes in the probability of recognition will be roughly proportional to changes in intensity.

## FLARE APPLICATIONS

There are three general categories into which the uses of illuminating flares fall and these can be useful in describing and defining specific figures of merit related to the effectiveness of each flare. They are:

### Fixed Position

This situation would exist when a target is at a known location such as a bridge or bunker and that target must be illuminated to direct lethal fire or assess damage.

### Specific Areas

In this situation an area must be illuminated to a level that if a target were present the observer would have a very high probability of recognition. This would be employed when securing an area against infiltration by enemy troops.

### Search

This situation considers the probability of finding a target in a very large suspect area. This may arise when an aircraft searches for the location of enemy vehicles or positions.

## FIGURES OF MERIT

In order to examine the effect of changes in intensity for each of these situations, it is necessary to specify both the flare type and the range of the observer from the target. An approach can be used similar to the one taken by Dr. M. Messinger in his notes on "The Time Fuze Accuracy Requirements for Illuminating Mortar Projectiles," dated April 1972, to determine a figure of merit for each flare application.

It has been shown in PATR 4184 that the illumination required for a 90% probability of recognition is a function of the relative angle of the observer, flare, and target as well as the range. Also, the illumination required for a 90% probability of recognition in a given target situation,  $R$ , is a function of the flare coordinates  $x_f, y_f, h$ ; target coordinates  $x_t, y_t$ ; and observer coordinates  $x_o, y_o$  so that

$$\underline{R} = R(x_f, y_f, h, x_t, y_t, x_o, y_o).$$

### Fixed position

In the case where it is necessary to illuminate a fixed position, if we assume that  $L$  is the actual target illumination and  $R$  is the critical illumination level, we define the step function  $u(L - R)$  such that  $u = 0.9$  when  $L \geq R$  and  $u = P$  when  $L < R$ ,  $P$  being the probability of recognition as shown in Figure 6 and defined by the empirical equation

$$P = 1.25e^{-\frac{0.42}{F}} + 0.031$$

where  $F$  is the fraction of critical illumination at the target,  $F = \frac{L}{R}$ . A figure of merit ( $E_f$ ) relating to the effectiveness of a flare for the fixed position illumination case can be defined as

$$E_f = \int_0^T u(L - R) dt$$

where the integral is taken over the total burning time of the flare. By varying the intensity ( $I$ ) in the illumination equation, ( $L$ ), of the search case, one may compare the relative figures of merit for a given observer, target and source location and be able to analyze the effects of flare variations on effectiveness.

### Specific Area

For the case where it is necessary to illuminate a specific area above the critical illumination level such as in anti-intrusion, perimeter defense, etc, we define the step function  $u(L - R)$  such that  $u = .9$  when  $L \geq R$  and  $u = 0$  when  $L < R$ . A figure of merit for the area illumination case ( $E_a$ ) can then be defined such that

$$E_a = \int_0^T \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} u(L - R) dx dy dt$$

## Search

In the case where a large area is to be searched for targets and only a small portion of the suspect area can be illuminated, we again define a function  $u(L - R)$  such that when  $L \geq R$ ,  $u = 0.9$  and when  $L < R$ ,  $u = P$  where  $P$  is again the probability of recognition as shown in Figure 6.

The figure of merit,  $E_s$ , in this case can be considered to be the integral

$$E_s = \int_0^T \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} u(L - R) dx dy dt$$

## APPROXIMATE EFFECTS

### Fixed Position

In this case, estimates of how changes in intensity of the flare affect recognition performance can be made fairly easily. If it is assumed that the position of the flare remains the same relative to the target, changes in the probability of recognition would be affected exactly as shown in Figure 6; that is, when the illumination is above the critical illumination level there would be little effect on the probability of recognition. When the illumination is below this level, it would correspond to the slope of this curve (Fig 6) which varies from  $1/3$  to  $3/2$ . For most practical ranges, the illumination level would be below the critical illumination level and in these applications it can be roughly estimated that changes in the intensity would affect the performance proportionately.

### Specific Area

In this report for a first approximation it will be assumed that the critical illumination level is dependent only on the range of the target from the observer, and the effect of changes in intensity for three illumination rounds at three ranges will be examined.

The following operational characteristics were used in this calculation for these three items:

Type of round	Candlepower (x 1000)	Ignition altitude	
		(feet)	(meters)
60 mm mortar	320	600	200
81 mm mortar	500	1000	330
155 mm howitzer	1000	1800	590

PATR 4184 provides the approximate critical illumination levels as a function of range:

Range		Illumination level, $E_o$ (footcandles)
(feet)	(meters)	
800	260	0.04
3000	980	0.40
5000	1640	1.00

The results are shown in Tables 1, 2, and 3. From these results it can be seen that for short ranges where the critical illumination level is low the change in area illuminated to the critical illumination level (approximately 90% probability of recognition) is roughly proportional to the change in intensity. As the range increases, the change in area becomes more sensitive to changes in flare intensity, as much as five times in the case of the 81 mm mortar. In addition as this sensitivity increases the flare becomes very ineffective for recognition purposes since it illuminates a smaller and smaller area to the critical value. For example, in the case of the 81 mm mortar flare at a range of 980 m (3000 ft), a 5% change in flare intensity results in a 25% change in the area effectively illuminated to the 90% probability of recognition. The area illuminated to the critical value for 90% recognition is only  $7.85 \times 10^5$  square feet at the 980 m (3000 ft) range as compared to an area of  $3.6 \times 10^7$  square feet illuminated to the critical level for the same flare at the 260 m (800 ft) range. It appears from these data then, that in the Specific Area case that percent changes in intensity influence the effectiveness at least proportionately and probably no more than double for practical ranges of the item.

## Search

If the same rough assumptions are made as in the Specific Area Case and if the same operational calculations for the items are used, then the effect of changes in intensity on effectiveness is shown in Tables 4, 5, and 6. Again it appears from these data that in the Search Case changes in intensity influence the effectiveness at least proportionately and may generate changes in the effectiveness by as much as twice the percentage change in intensity.

## CONCLUSIONS

Changes in recognition probability are roughly proportional to changes in intensity when the target is in a fixed, known position and the illumination is at the critical illumination level or lower.

In the case of illuminating an area to a high probability of recognition, fractional degradation in intensity of the candle can produce more than double the degradation in performance; however, this occurs in an area where the flare performance is poor anyway.

The possible change in effectiveness of recognizing a target anywhere in a large search area illuminated by a flare appears to range between one and two times the percentage change in intensity for all practical ranges and conditions of use.

For a rough estimate of the degradation of a flare for use in evaluating specifications, it can be expected that, generally, degradation in effectiveness is at least proportional to degradation in intensity and would probably not be more than twice the percentage degradation in intensity of a flare for any practical range. However, before any production specifications on flare intensity are written, rigorous calculations should be performed to show the expected degradation of the performance of the flare. These calculations should utilize the data on each type of flare, the angular relations and intensity requirements found in PATR 4184, and the mathematical approach formulated in this report.

Table 1

Effect of flare intensity on area illuminated<sup>a</sup>

Decrease in intensity (%)	Round	60 mm Mortar		81 mm Mortar		155 mm Howitzer		
	Range	(feet)	800	3000	800	3000	800	3000
		(meters)	260	980	260	980	260	980
	CIL <sup>c</sup>	(footcandles)	0.04	0.4	0.04	0.4	0.04	0.4
	Decrease in 90%-recognition area <sup>b</sup> (%)							
5			5.23	9.10	5.40	25	5.75	<sup>d</sup>
10			10.45	18.20	10.80	50	11.50	
15			15.68	27.30	16.20	75	17.30	
20			20.90	36.40	21.60	100 <sup>d</sup>	23.00	
25			26.13	45.50	27.00		28.80	
30			31.35	54.60	32.50		34.50	
35			36.58	63.70	37.90		40.30	
40			41.80	72.80	43.20		46.00	

<sup>a</sup>Specific area case; at ignition altitude.<sup>b</sup>There is no 90%-recognition area at a range of 1640 m (5000 ft) and a CIL of 1 footcandle.<sup>c</sup>Critical illumination level.<sup>d</sup>Under these conditions there is no 90%-recognition area.

Table 2

Effect of flare intensity on target recognition<sup>a</sup>

Decrease in intensity (%)	Round	60 mm Mortar			81 mm Mortar			155 mm Howitzer			
	Range	(feet)	800	3000	5000	800	3000	5000	800	3000	5000
		(meters)	260	980	1640	260	980	1640	260	980	1640
	CIL <sup>b</sup>	(footcandles)	0.04	0.4	1.0	0.04	0.4	1.0	0.04	0.4	1.0
Decrease in target-recognition probability (%)											
5			4.9	4.5	7.7 <sup>c</sup>	5.4	7.3	8.7 <sup>f</sup>	5.4	7.6 <sup>d</sup>	7.8 <sup>h</sup>
10			10.2	12.3	11.5 <sup>d</sup>	10.8	13.8	16.2	11.0	15.5 <sup>d</sup>	22.1 <sup>h</sup>
20			20.2	22.6	29.6 <sup>d</sup>	20.6	27.0	35.0	21.0	30.3 <sup>e</sup>	43.0 <sup>i</sup>
40			40.6	46.0	56.5 <sup>f</sup>	41.4	52.9	60.2	41.9	54.3 <sup>f</sup>	76.1 <sup>i</sup>

<sup>a</sup>Search case; at ignition altitude<sup>b</sup>Critical illumination level<sup>c</sup>Maximum recognition probability possible 80%, <sup>d</sup>70%, <sup>e</sup>60%, <sup>f</sup>50%, <sup>g</sup>40%, <sup>h</sup>30%, <sup>i</sup>20%, <sup>j</sup>10%.

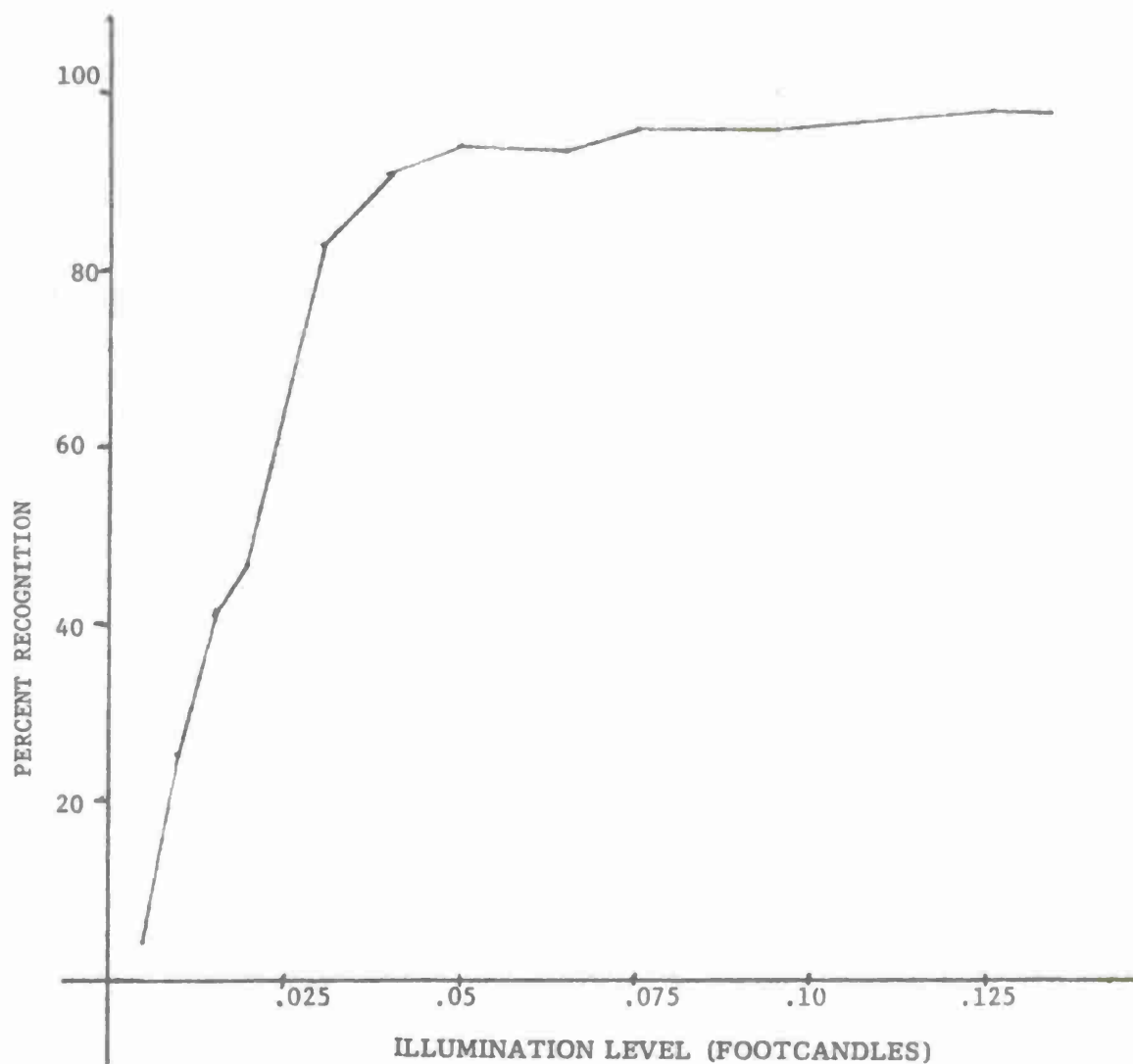


Fig 1 Recognition response to vehicular size targets against a medium green background at a simulated range of 490 m (1500 ft) and a target illumination angle of 124°

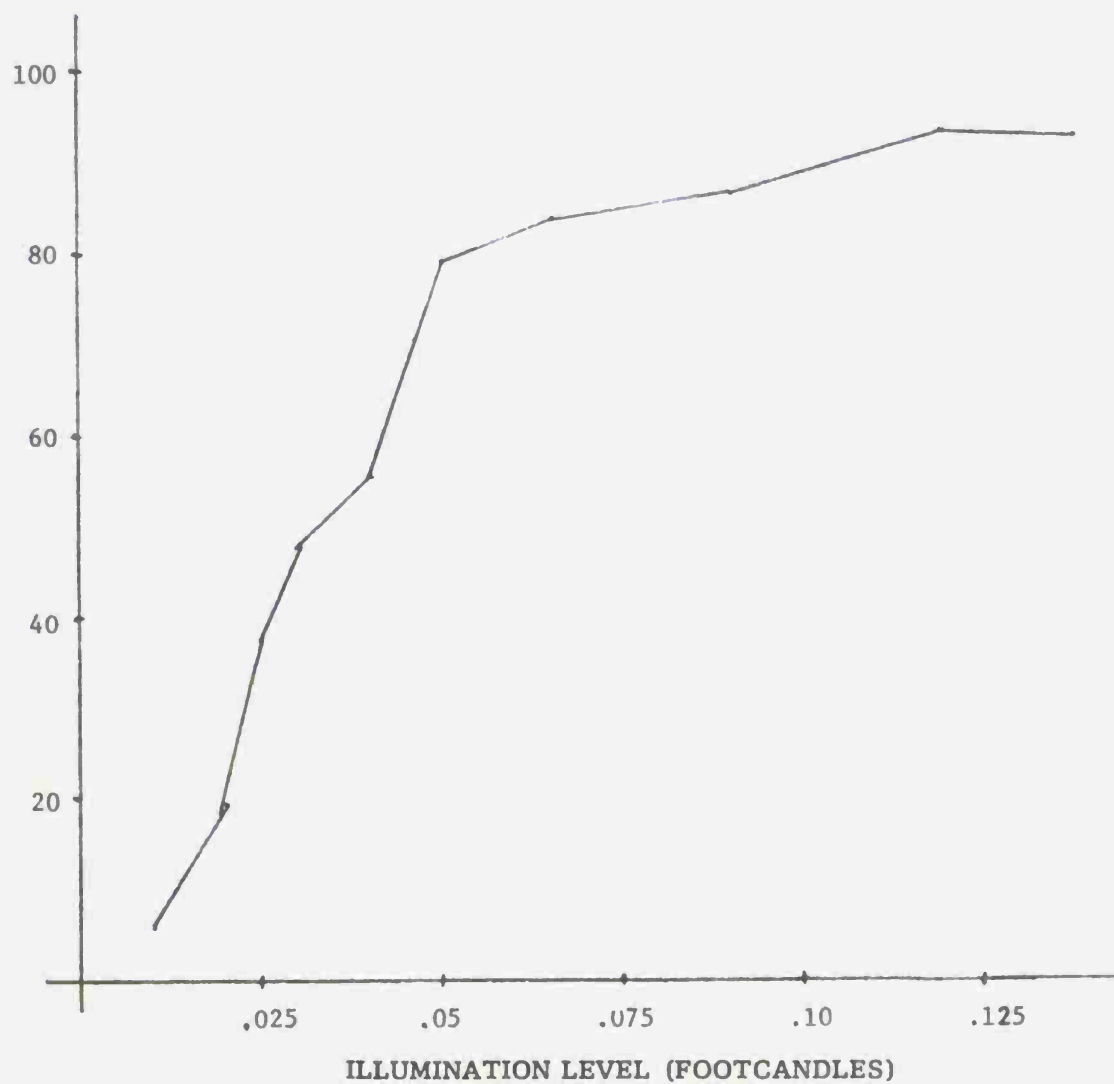


Fig 2 Recognition response to vehicular size targets against a dark green background at a simulated range of 654 m (2000 ft) and a target illumination angle of 90°

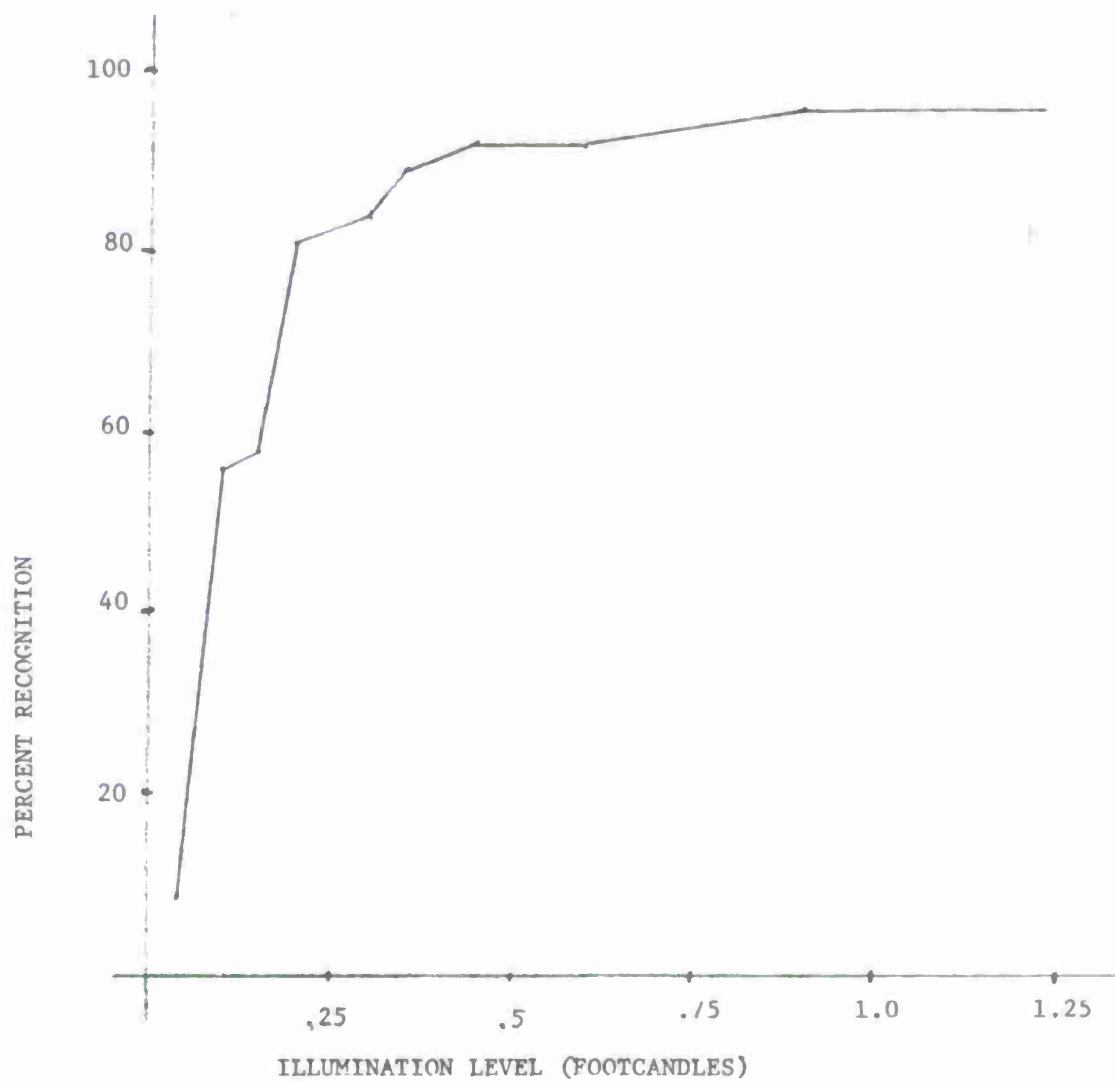


Fig 3 Recognition response to vehicular size targets against a medium green background at a simulated range of 980 m (3000 ft) and a target illumination angle of  $110^\circ$

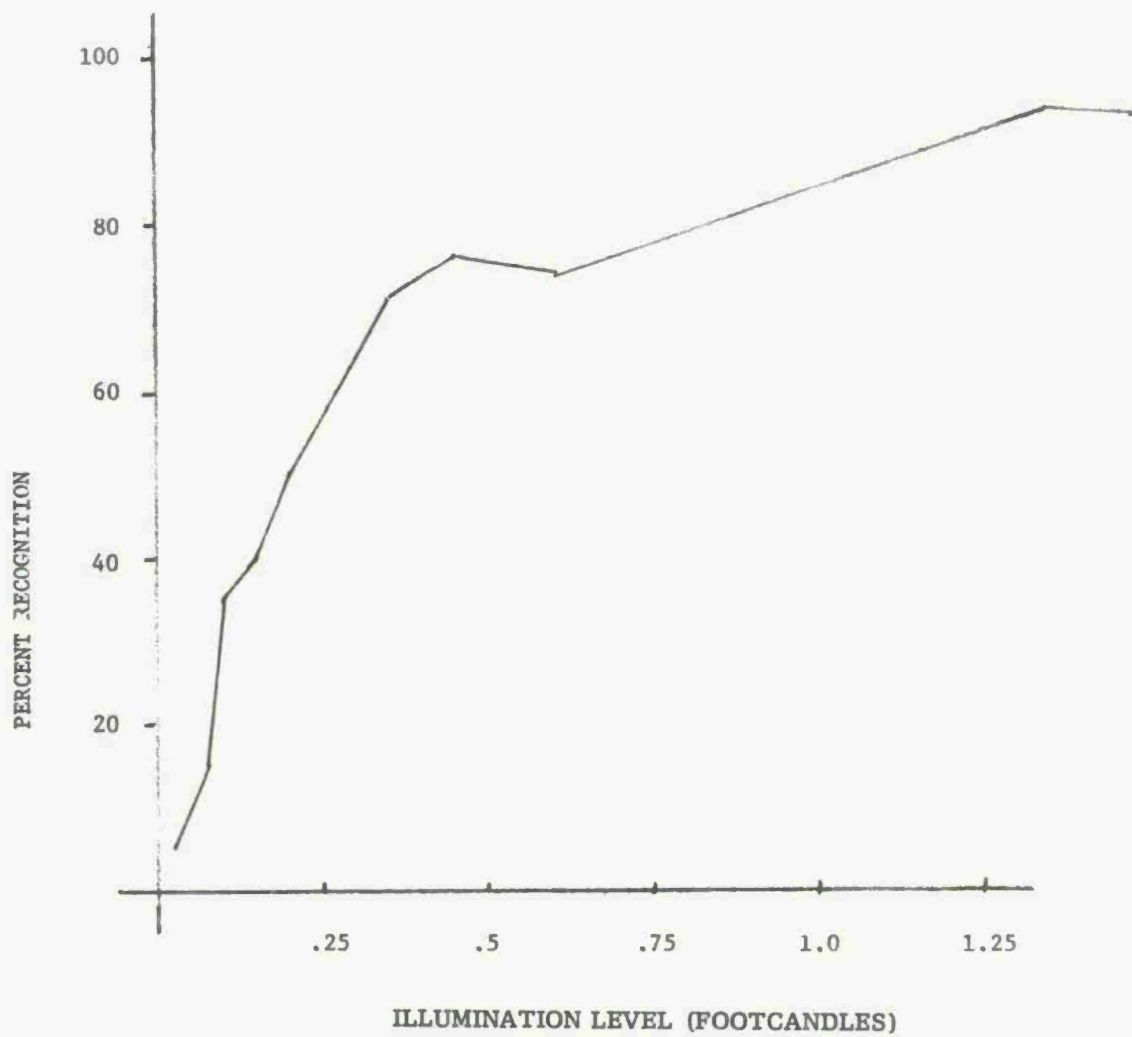


Fig 4 Recognition response to vehicular size targets against a dark green background at a simulated range of 1150 m (3500 ft) and a target illumination angle of 70°

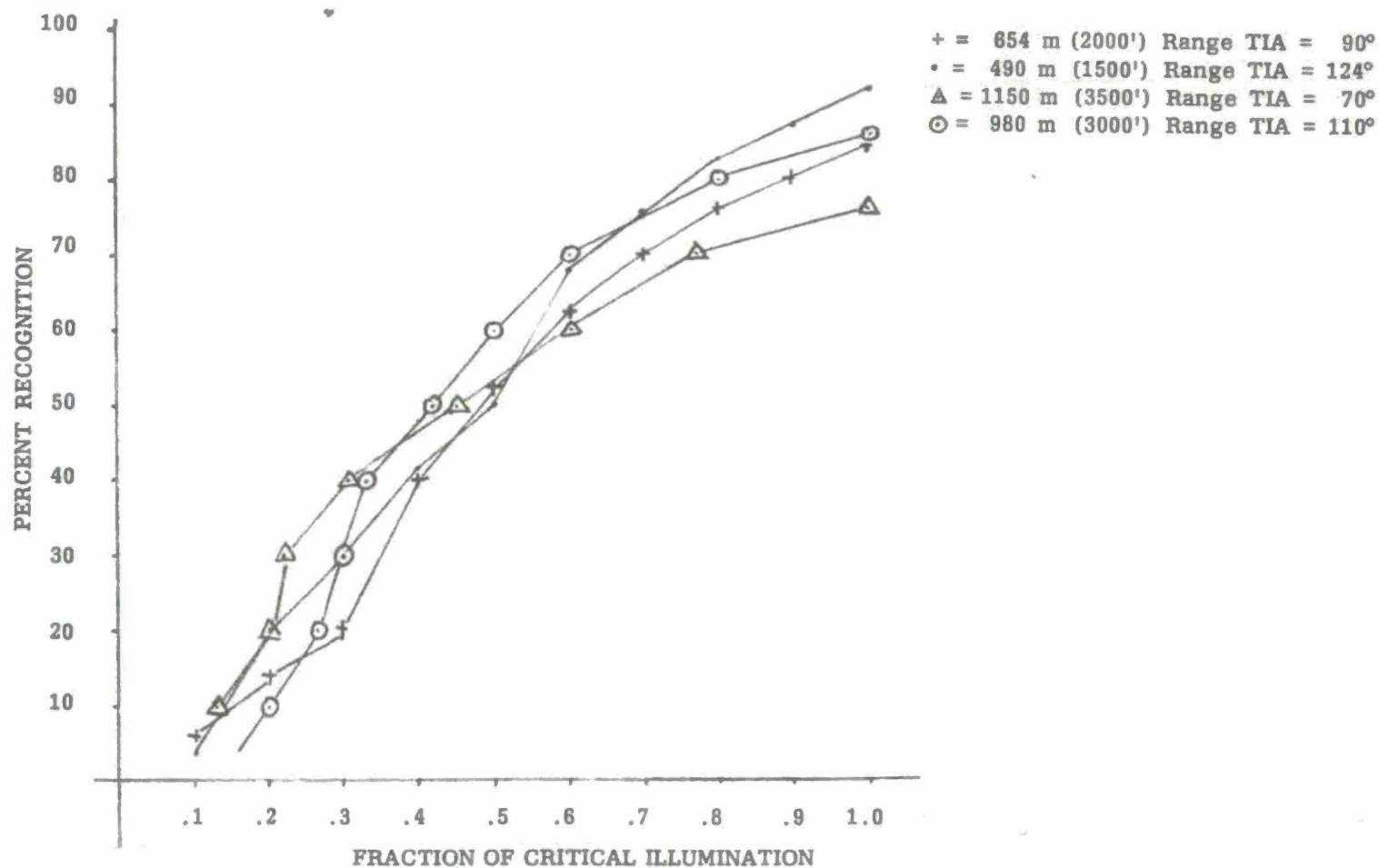


Fig 5 Portions of the response curve normalized at the critical illumination level

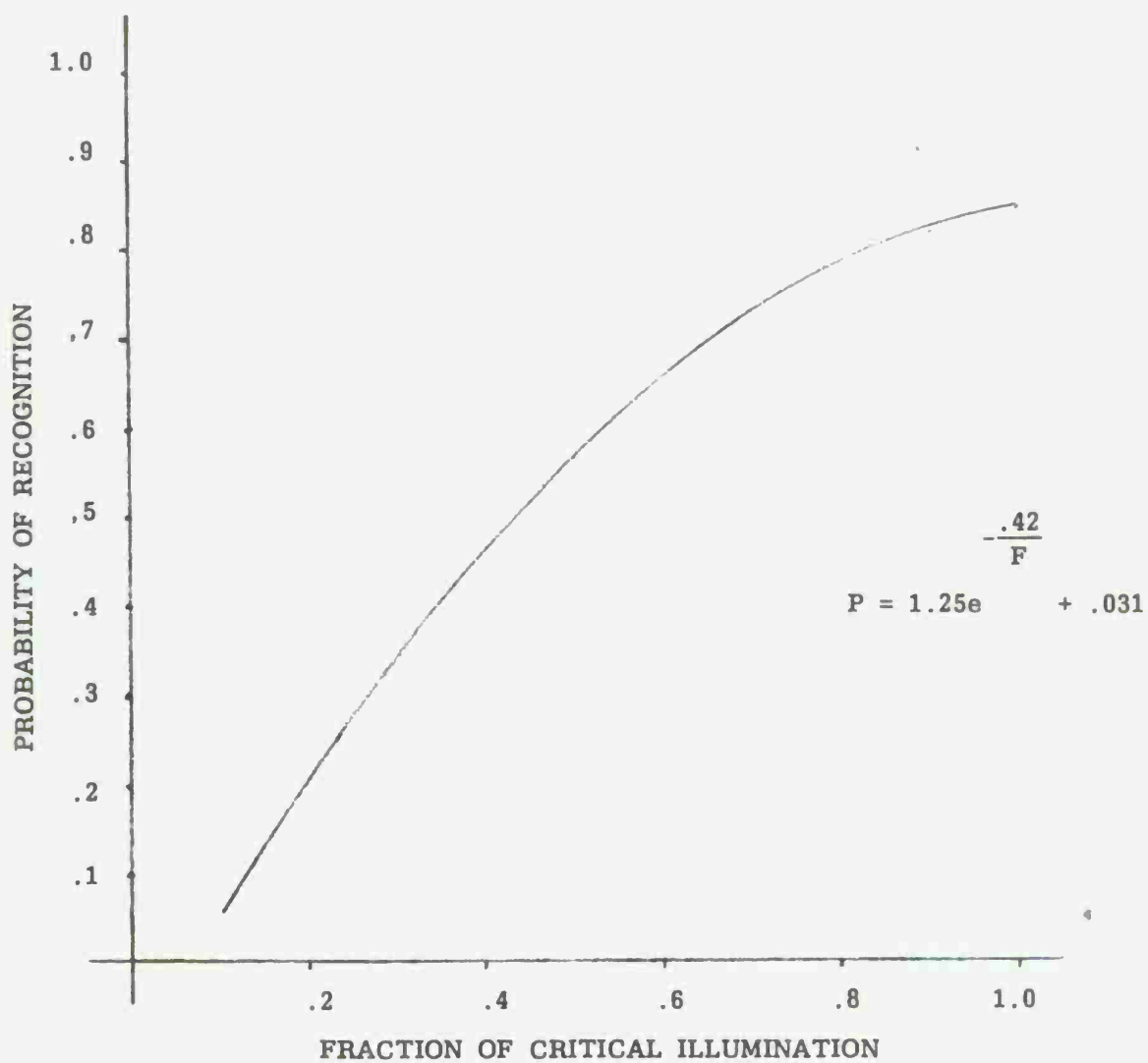


Fig 6 Average curve of the four normalized response curves

## DISTRIBUTION LIST

Metals and Ceramics Information Center  
ATTN: Mr. Harold Mindlin, Director  
Mr. James Lynch, Asst Director  
505 King Avenue  
Columbus, OH 43201

Commander  
Defense Documentation Center (12)  
Cameron Station,  
Alexandria, VA 22314

Commander  
US Army Foreign Science & Technology Center  
ATTN: DRXST-SD3  
220 Seventh Street NE  
Charlottesville, VA 22901

Office of the Deputy Chief of Staff for Research,  
Development and Acquisition  
ATTN: DAMA-ARZ-E  
DAMA-CSS  
Washington, DC 20310

Commander  
Army Research Office  
ATTN: Dr. George Mayer  
Mr. J. J. Murray  
P.O. Box 12211  
Research Triangle Park, NC 27709

Commander  
US Army Materiel Development & Readiness Command  
ATTN: DRCQA-E  
DRCQA-P  
DRCDE-D  
DRCDDMD-FT  
DRCLDC  
DRCMT  
DRCMM-M  
Alexandria, VA 22333

Commander  
US Army Electronics Command  
ATTN: DRSEL-PA-E, Mr. Stan Alster (2)  
Fort Monmouth, NJ 07703

Commander  
US Army Missile Research & Development Command  
ATTN: DRDMI-TB, Redstone Scientific Information Center (2)  
DRDMI-TK, Mr. J. Alley  
DRSMI-M  
DRDMI-ET, Mr. Robert O. Black  
DRDMI-QS, Mr. George L. Stewart, Jr.  
DRDMI-EAT, Mr. R. Talley  
DRDMI-QP  
Redstone Arsenal, AL 35809

Commander  
US Army Troop Support and Aviation Materiel Readiness Command  
ATTN: DRSTS-PLE, Mr. J. Corwin  
DRSTS-Q  
DRSTS-M  
4300 Goodfellow Boulevard  
St. Louis, MO 63120

Commander  
US Army Natick Research & Development Command  
ATTN: DRXNM-EM  
Natick, MA 01760

Commander  
US Army Mobility Equipment Research & Development Command  
ATTN: DRDME-D  
DRDME-E  
DRDME-G  
DRDME-H  
DRDME-M  
DRDME-T  
DRDME-TQ  
DRDME-V  
DRDME-ZE  
DRDME-N  
Fort Belvoir, VA 22060

Commander  
US Army Tank-Automotive Materiel Readiness Command  
ATTN: DRSTA-Q (2)  
Warren, MI 48090

Commander  
US Army Armament Materiel Readiness Command  
ATTN: DRSAR-QA (2)  
DRSAR-SC  
DRSAR-RDP  
DRSAR-EN  
DRSAR-QAE  
DRSAR-LEP-L  
Rock Island, IL 61299

Commander  
US Army Armament Research & Development Command  
ATTN: DRDAR-LC, Mr. E. Kelly  
DRDAR-LCA, Dr. Sharkoff  
DRDAR-LCE, Dr. R. Walker  
DRDAR-QAS, Mr. F. Fitzsimmons (5)  
DRDAR-SCM, Dr. J. Corrie  
DRDAR-TSP, Mr. B. Stephans  
DRDAR-TSS (5)  
Dover, NJ 07801

Commander  
US Army Aviation R&D Command  
ATTN: DRDAV-EXT  
DRDAV-QR  
DRDAV-QP  
DRDAR-QE  
St. Louis, MO 63166

Commander  
US Army Tank-Automotive Research & Development Command  
ATTN: DRDTA-RKA, Mr. D. Matichuk  
DRDTA-RKA, Mr. R. Dunec  
DRDTA-RKA, Mr. S. Catalano  
DRDTA-JA, Mr. C. Kedzior  
DRDTA-UL, Technical Library  
Warren, MI 48090

Director  
US Army Industrial Base Engineering Activity  
ATTN: DRXPE-MT, Dr. W. T. Yang  
Rock Island, IL 61299

Commander  
Harry Diamond Laboratories  
ATTN: DRXDO-EDE, Mr. B. F. Willis  
2800 Powder Mill Road  
Adelphi, MD 20783

Commander  
US Army Test & Evaluation Command  
ATTN: DRSTE-TD  
DRSTE-ME  
Aberdeen Proving Ground, MD 21005

Commander  
US Army White Sands Missile Range  
ATTN: STEWS-AD-L  
STEWS-ID  
STEWS-TD-PM  
White Sands Missile Range, NM 88002

Commander  
US Army Yuma Proving Ground  
ATTN: Technical Library  
Yuma, AR 85364

Commander  
US Army Tropic Test Center  
ATTN: STETC-TD, Drawer 942  
Fort Clayton, Canal Zone

Commander  
Aberdeen Proving Ground  
ATTN: STEAP-MT  
STEAP-TL  
STEAP-MT-M, Mr. J. A. Feroli  
STEAP-MT-G, Mr. R. L. Huddleston  
Aberdeen Proving Ground, MD 21005

Commander  
US Army Cold Region Test Center  
ATTN: STECR-OP-PM  
APO Seattle, WA 98733

Commander  
US Army Dugway Proving Ground  
ATTN: STEDP-MT  
Dugway, UT 84022

Commander  
US Army Electronic Proving Ground  
ATTN: STEEP-MT  
Ft. Huachuca, AR 85613

Commander  
Jefferson Proving Ground  
ATTN: STEJP-TD-I  
Madison, IN 47250

Commander  
US Army Aircraft Development Test Activity  
ATTN: STEBG-TD  
Ft. Rucker, AL 36362

President  
US Army Armor and Engineer Board  
ATTN: ATZKOE-TA  
Ft. Knox, KY 40121

President  
US Army Field Artillery Board  
ATTN: ATZR-BDOP  
Ft. Sill, OK 73503

Commander  
Anniston Army Depot  
ATTN: SDSAN-QA  
Anniston, AL 36202

Commander  
Corpus Christi Army Depot  
ATTN: SDSCC-MEE, Mr. Haggerty  
Mail Stop 55  
Corpus Christi, TX 78419

Commander  
Letterkenny Army Depot  
ATTN: SDS-LE-QA  
Chambersburg, PA 17201

Commander  
Lexington-Bluegrass Army Depot  
ATTN: SDSRR-QA  
Lexington, KY 40507

Commander  
New Cumberland Army Depot  
ATTN: SDSNC-QA  
New Cumberland, PA 17070

Commander  
US Army Depot Activity, Pueblo  
ATTN: SDSTE-PU-O  
Pueblo, CO 81001

Commander  
Red River Army Depot  
ATTN: SDSRR-QA  
Texarkana, TX 75501

Commander  
Sacramento Army Depot  
ATTN: SDSSA-QA  
Sacramento, CA 95813

Commander  
Savanna Army Depot Activity  
ATTN: SDSSV-S  
Savanna, IL 61074

Commander  
Seneca Army Depot  
ATTN: SDSSE-R  
Romulus, NY 14541

Commander  
Sharpe Army Depot  
ATTN: SDSSH-QE  
Lathrop, CA 95330

Commander  
Sierra Army Depot  
ATTN: SDSSI-DQA  
Herlong, CA 96113

Commander  
Tobyhanna Army Depot  
ATTN: SDSTO-Q  
Tobyhanna, PA 18466

Commander  
Tooele Army Depot  
ATTN: SDSTE-QA  
Tooele, UT 84074

Director  
DARCOM Ammunition Center  
ATTN: SARAC-DE  
Savanna, IL 61074

Naval Research Laboratory  
ATTN: Dr. J. M. Krafft, Code 8430  
Library, Code 2620  
Washington, DC 20375

Director  
Air Force Materiel Laboratory  
ATTN: AFML-DO, Library  
AFML-LTM, Mr. E. Wheeler  
AFML-LLP, Mr. R. Rowand  
Wright-Patterson AFB, OH 45433

Weapon System Concept Team/CSL  
ATTN: DRDAR-ACW  
Aberdeen Proving Ground, MD 21010

Technical Library  
ATTN: DRDAR-CLJ-L  
Aberdeen Proving Ground, MD 21010

Technical Library  
ATTN: DRDAR-TSB-S  
Aberdeen Proving Ground, MD 21005

Benet Weapons Laboratory  
Technical Library  
ATTN: DRDAR-LCB-TL  
DRDAR-LCB, Mr. T. Moraczewski  
Watervliet, NY 12189

Director  
US Army TRADOC Systems Analysis Activity  
ATTN: ATAA-SL, Technical Library  
White Sands Missile Range, NM 88002

Director  
Army Materials and Mechanics Research Center  
ATTN: DRXMR-P  
DRXMR-PL (2)  
DRXMR-M (2)  
DRXMR-MQ  
DRXMR-MI, Mr. Darch  
DRXMR-L, Dr. Chait  
DRXMR-RA, Mr. Valente  
Watertown, MA 02172

Commander  
Chemical Systems Laboratory  
ATTN: DRDAR-CLR, Mr. Montaway  
DRDAR-QAC, Dr. Moritz  
Aberdeen Proving Ground, MD 21010

